#7566 EFFECT OF INTERCROPPING SORGHUM WITH COWPEA AND NITROGEN APPLICATION ON GROWTH AND YIELD OF SORGHUM (Sorghum bicolor (L.) MOENCH)

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ABSTRACT

Despite the development of improved varieties, the yield of sorghum has remained significantly low in dryland environments due to low soil fertility and inappropriate cropping practices. However, implementation of precision agriculture (PA) within the context of companion cropping with legumes and fine-tuning the supply of fertilizer nitrogen (N) has the potential to increase sorghum yield in these environments. The objective of this study was to determine the effect of intercropping and fertilizer N rate on growth and yield of selected varieties of sorghum. Results showed that intercropping significantly reduced crop growth rate (CGR) of sorghum by 54% compared with sole crop system. Addition of N increased sorghum CGR by 30% but no differences were detected between 40 and 80 kg N ha^{-1}. Under sole crop system, Gadam out-yielded Serena by 1.3 t ha^{-1} in Igoji but there were no differences in yield between the two varieties in Katumani which was drier than the former. However, intercropping significantly reduced the grain yield of both sorghum varieties by about 50% irrespective of the cowpea variety. Addition of N increased grain yield by at least 26% in both sites but yield differences between 40 and 80 kg N ha^{-1} were marginal under both sole crop and intercrop systems. Cropping system × N interaction effects on grain yield were significant in Igoji only, where N increased sorghum grain yield under sole crop system but higher N rates only marginally increased yield under intercrop. Although intercropping reduced sorghum yield, present results show that there is potential to exploit cropping system × N interactions to increase yields, more so in wet environments than in areas with low rainfall. Lack of significant differences in grain yield between the application of 40 and 80 kg N ha^{-1} suggests that sorghum yield could be maximized at lower N rates. However, further studies are needed to establish the economically optimal N rate in sorghum production.

Keywords: cropping system, crop growth rate, drylands, interactions

INTRODUCTION

The increased demand to enhance food production to feed a rapidly growing population has progressively worsened primary resources such as soil, water and atmosphere (Mariangela et al., 2012). Precision agriculture has been investigated in previous studies and is considered a win–win solution both for improving crop yields and environmental quality of agriculture (Mariangela et al., 2012). Sorghum (*Sorghum bicolor* (L.) Moench) is an essential cereal as a food security crop and a raw material for making malt thus, increasing its productivity could end severe food insecurity and increase incomes of smallholder farmers in the dryland environments due to its unique traits of tolerating moisture stress and high yielding ability in a wide range of soils (Mwadalu and Mwangi, 2013). However, despite the development of improved varieties, the yield of sorghum has remained significantly low in dryland environments due to low soil fertility and inappropriate cropping practices (Kilambya and Witwer, 2013). Therefore, implementation of precision agriculture approaches in sorghum production within the context of companion cropping with legumes and variable rate of nitrogen fertilizer application could improve sorghum yields, fertilizer use efficiency and profitability as well as reduce negative environmental consequences (Mariangela et al., 2012).

Cereal-legume intercropping is a sustainable agricultural practice where more than two crops are grown simultaneously on the same land (Sibhatu & Belete, 2015). In comparison with sole crop systems, intercropping improves crop diversification, increases crop yields and stability, especially under low-input conditions, improves soil fertility and conservation, as well as weed control (Oseni, 2010; Layek et al., 2018). Nitrogen (N) is among the most deficient nutrients in many agricultural soils for cereal production on a global basis but is essential in crop growth (Yagoub and Abdelsalam, 2010). The N fertilizer application rates in sorghum production often vary across environments and cropping systems. An earlier study reported that maximum grain yield of sorghum in cereal-legume intercrop system was attained with addition of 41 kg N ha^{-1} in dry environment (Sibhatu & Belete, 2015). However, Shamme & Raghavaiah (2016) reported that under sole crop system, the highest sorghum grain yield was recorded with the application of 92 kg N ha^{-1} while the lowest grain yield was recorded with no nitrogen application. Additionally, higher crop yields have been attained by increasing N addition across environments (Dobermann, 2007). While N is limiting in most agriculture soils, it's a very mobile element in the soil and susceptibility to loses through leaching, denitrification, volatilization and runoff thus, farmers have resorted to excessive application of N fertilizers in the agricultural systems to compensate for these losses (Shamme and Raghavaiah, 2016). This excessive use of N fertilizers often causes environmental pollution, weed problems, sorghum susceptibility to diseases, lodging, delayed maturity thus, precision farming techniques such as appropriate fertilizer placement method at the correct rate and right time when the plant needs the nutrients and variable-rate N fertilizers are required to increase productivity, efficient use of inputs and reduce negative environmental impact (Dobermann, 2007; Mariangela et al., 2012). However, little information exists on the appropriate N rate for sorghum production in a sorghum-legume intercrop system in dry and medium potential environments. Thus, the objective of this study was to determine the effect of intercropping and fertilizer N rate on growth and yield of selected varieties of sorghum.

MATERIALS AND METHODS

Two field experiments were simultaneously conducted under rain-fed conditions at the Kenya Agricultural and Livestock Research Organization (KALRO) stations in Katumani and Igoji during 2018/2019 short rains. Experiments were laid out in randomized complete block design with split plot arrangement replicated three times. Treatments comprised two cropping systems (intercrop vs. sole crop) with two varieties of sorghum (Gadam and Serena) and two cowpea varieties (M66 and K80), and three rates of fertilizer nitrogen (0, 40 and 80 kg N ha^{-1}). Fertilizer N was supplied from urea (46% N) and side banded on both sorghum and cowpea in fractions of a third at sowing and two-thirds top dressed at tillering stage of sorghum growth. All treatment plots received 60 P kg ha^{-1} of basal fertilizer in the form of triple super phosphate that was banded on the planting rows of both crops.

Sorghum was sampled for shoot biomass at flowering and physiological maturity and crop growth rate (CGR) (g m^{-2} day^{-1}), computed between the two stages. Yield components were collected from a net area of 16 m^{2}, and included panicle length, grain yield and weight. Data were subjected to the analysis of variance using GenStat 14th Edition. Treatment means were compared and separated using least significant difference (LSD) test at 5%cprobability level.

RESULTS AND DISCUSSION

Crop growth rate (CGR) did not significantly differ between Gadam and Serena in both sites but cropping system significantly affected this trait in Igoji (P = 0.002) and Katumani (P = 0.016) (Table 1). In both sites, intercropping significantly reduced sorghum growth rate by 2.4 g m^{-2} day^{-1}, irrespective of the cowpea variety. Addition of N significantly increased sorghum growth rate only in Igoji (P = 0.002) where application of 80 kg N ha-1 increased overall CGR by 1.6 g m^{-2} day^{-1} (30%) compared with control plots but without significant differences between 40 and 80 kg N ha^{-1}. Cropping system × N rate effect CGR was significant in Igoji (P <.001) and Katumani (P = 0.042). Under sole cropping system, sorghum CGR increased with additional N but marginal effects were observed under the intercrop system.

Sorghum grain yield was significantly affected by the cropping system (P <.001) in both sites, N rate in Igoji (P <0.01) and Katumani (P = 0.013) while cropping system × N rate interactions only occurred in Igoji (P <0.01) (Table 1). Under sole crop system, Gadam out-yielded Serena by 1.3 t ha^{-1} in Igoji but there were no differences in yield between the two varieties in Katumani. However, intercropping significantly reduced the grain yield of both sorghum varieties by about 50%, irrespective of the cowpea variety. Addition of fertilizer increased grain yield by at least 26% in both sites but yield differences between 40 and 80 kg N ha^{-1} were marginal under both sole crop and intercrop systems. Cropping system × N rate effect on sorghum grain yield in Igoji revealed that while sorghum grain yield increased with the addition of N under sole crop system, higher N rates only marginally increased yield under intercropping system. Intercropping sorghum with either cowpea variety significantly reduced 1000 seed weight. However, the addition of N and its interaction with cropping system did not affect 1000-seed weight in both sites.

The reduction in the grain yield and CGR of intercropped sorghum could be attributed to interspecies competition for resources like soil nutrients, sunlight and water in the intercrop system which affected growth of vegetative and reproductive parts (stems, leaves and panicles) resulting into low biomass production and grain yield (Oseni, 2010; Makoi et al., 2010; Legwaila et al., 2012; Karanja et al., 2014; Sibhatu and Belete, 2015). However, the increase in CGR and grain yield with addition of N could be attributed to the important role of N in increasing growth and development of plant reproductive parts and photosynthetic capacity suggesting that proper rate and time of N application are critical for meeting crop nutrient needs and increases CGR and grain yield (Shamme & Raghavaiah, 2016; Yang et al. (2018). The interaction of cropping system × nitrogen treatments were significant where the highest CGR and mean grain yield was recorded under sole but only marginal increase in intercrop system was observed. This could have been attributed to non-proportional sharing of soil N sources resulting from competition between sorghum and cowpea and limited fixation of N by the cowpea in an intercrop system resulting to low grain yield in an intercrop system as opposed to sole cropping system (Jensen et al., 2020). Therefore, the study findings suggest that Gadam variety was superior to Serena in terms of growth and yield and sole cropping system with addition of N was effective in achieving maximum CGR and grain yield. However, present results also show that there is potential to exploit cropping system × N interactions to increase yields, more so in wet environments than in areas with low rainfall despite grain yield reduction in an intercrop system.

CONCLUSIONS

The overall findings suggest that sole cropping system and split application of N fertilizer was effective in increasing sorghum crop growth rate and yield compared with intercropping system and no fertilizer application. Additionally, although intercropping reduced CGR and sorghum grain yield by about 50%, present results show that there is potential to exploit cropping system × N interactions to increase yield, more so in wet environments than in areas with low rainfall. Lack of significant differences in grain yield between the application of 40 and 80 kg N ha^{-1} suggests that sorghum yield could be maximized at lower N rates, and further studies are needed to establish the economically optimal N rate.

Table 1. Crop growth rate (CGR) and grain yield of two sorghum varieties (Gadam and Serena) grown under sole and intercrop system with two varieties of cowpea (K80 and M66), and at three N rates at KALRO research stations in Igoji and Katumani during 2018/2019 short rain season.

Treatments	Igoji			Katumani		
	CGR (g m^{-2} day^{-1})	Grain yield (t ha^{-1})	Seed weight (g)	CGR (g m^{-2} day^{-1})	Grain yield (t ha^{-1})	Seed weight (g)
Cropping system (CS)						
Sole Gadam	5.32ab	3.15a	31.1a	5.86ab	3.09a	33.6a
Gadam + K80	5.19ab	1.48bc	30.7a	3.74bc	0.89c	29.1b
Gadam + M66	6.17a	1.27bc	30.9a	7.69a	1.43b	32.9a
Sole Serena	4.35b	1.82b	27.4b	4.31bc	2.76a	30.1b
Serena + K80	4.88ab	1.06bc	26.1b	3.44bc	1.10bc	26.3c
Serena + M66	1.97c	0.95c	31.0a	1.94c	1.27bc	30.7b
P-value	0.002	<.001	0.002	0.011	<.001	<.001
N rate						
0 kg N ha^{-1}	3.67b	1.46b	30.06a	3.60a	1.43b	30.33a
40 kg N ha^{-1}	5.00a	1.57b	29.50a	5.11a	1.96a	30.72a
80 kg N ha^{-1}	5.27a	1.84a	29.06a	4.77a	1.88a	30.28a
P-value	0.002	0.015	0.341	0.157	0.013	0.803
P-value CS × N rate	<.001	<.001	0.236	0.042	0.061	0.761

Means within a column followed by the same letters are statistically similar; CS × N is interaction between cropping system (CS) and N rate, ns is not significant.

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